(12) EUROPEAN PATENT APPLICATION

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(54) Variable area turbine and control system therefor.

(57) A turbocharger (12) is provided with means (24) for varying the effective area of the turbine (14), including actuating means (26) for actuating said means (24) to achieve an effective area as a predetermined function of engine rpm, the function comprising a first portion (I) at high rpms that maintains the effective area substantially at its maximum area condition as established by peak engine operating pressures, a second portion (II) at lower rpms which maintains the effective area substantially in the minimum area condition and a third portion (III) intermediate the first and second portions having a characteristic that the effective area increases as an increasing function of engine rpm established by selected engine operating parameters, means (83) for generating a feedback signal representing the actual effective area and feeding the signal back to control means (28), and said control means (28) being responsive to the feeback signal to generate pulses applied to said actuating means (26) to correct the means (24) for varying the effective area of the turbine 914) to achieve said effective area as a predetermined function of engine rpm.

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"VARIABLE AREA TURBINE AND CONTROL SYSTEM THEREFOR"

DESCRIPTION

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The present invention relates to a variable area turbine and more specifically to a control system therefor, such a turbine is used in an i.c. engine, for example.

10

Turbochargers are used extensively in modern diesel engines to improve fuel economy and minimize noxious emissions. Such a turbocharger comprises a turbine wheel in a chamber within a turbine housing, a

15 compressor wheel and housing, and a central cast bearing housing between the wheels. The turbine wheel rotates when driven by exhaust gases from an internal combustion engine and causes the compressor wheel to which it is coupled to rotate and compress air, to be

20 supplied to the engine, at a rate that is greater than the rate the engine can naturally aspirate. The turbocharger pressure output is a function of component efficiencies, mass flow through the turbine

and compressor and the pressure drop across the
turbine.

One problem that occurs with turbochargers is
that acceleration of an engine from a relatively low
rpm is accompanied by a noticeable lag in the pressure
increase from the turbocharger resulting in a
noticeable lag in acceleration. The reason for this
is that the inlet area of the turbine is designed for
maximum rated conditions. As a result, the velocity
of the gases passing across the turbine wheel at low
engine rpm allow the turbocharger rpm to drop to such
at low level that a substantial increase in gas
velocity is required to increase the turbocharger rpm.

In order to overcome this deficiency, a number of
schemes have been proposed to provide the turbocharger
with a variable inlet area so that a low engine rpm
the area may be made small to increase the velocity of
the exhaust gases entering the turbine chamber and
maintain the turbocharger at a sufficiently high rpm
to minimize lag. Such schemes for varying the
effective inlet area of the turbine are commonly
referred to as variable geometry schemes or
arrangements.

Various schemes have been proposed to eliminate or reduce "turbo lag" by incorporating variable geometry into the turbine element of the turbocharger. For example FLAXINGTON D. and SZCZUPAK D.T. (1982) in their paper Variable Area Radial-Inflow Turbine Proceedings of the Conference on Turbo charging and Turbo chargers 26th to 28th April 1982 - Institution of Mechanical Engineers, pages 55 to 62, discuss various methods of controlling turbine effective area, the most common of which are compressor boost control systems which manipulate turbine effective area to attempt to maintain a pre-set compressor pressure output. While this type gives effective transient response, it will not necessarily give the turbine effective area at higher engine rpm that produces most efficient operation.

In order to improve the efficiency, it is proposed by FLAXINGTON and SZCZUPAK to control turbine effective area approximately proportional to engine rpm. However, this suggestion does not fully define those elements of the control scheme that truly provide optimum control.

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According to one aspect of the present invention there is provided in an internal combustion engine having a turbosupercharger including a compressor and a turbine and a means for varying the effective area

5 of the turbine, apparatus comprising: means for actuating said means for varying the effective area of the turbine to achieve an effective area as a predetermined function of engine rpm, said function comprising a first portion at high rpms that maintains

10 the effective area substantially in its maximum area condition as established by peak engine operating pressures, a second portion at lower rpms which maintains the effective area substantially in the minimum area condition and a third portion

15 intermediate the first and second portions and having as a characteristic that the effective area increases as an increasing function of engine rpm as established by selected engine operating parameters; means for generating a feedback signal representing the actual

20 effective area and feeding said signal back to control means, said control means being responsive to the feedback signal to generate pulses applied to said actuating means to correct the means for varying the effective area of the turbine to achieve said

effective area as a predetermined function of engine
rpm.

The invention will be more fully understood from
the following description of embodiments given by way
of example only with reference to the figures of the
accompanying drawings in which:

Figure 1   is a diagrammatic representation of a
turbocharged engine with a variable area turbine
control system that embodies the present invention;

Figure 2   illustrates the functional
relationship between the turbine area and engine rpm
for the control system of Figure 1;

Figure 3   shows one embodiment of the control
system of Figure 1 which employs fluid pressure to
vary the area of the turbine;

Figure 4   is a sectional view of part of the
turbine poriton of the turbocharger, and of the
actuator assembly for the control system of Figure 3;

Figure 5   shows another embodiment of the
control system of Figure 1 which also employs fluid
pressure to vary the area of the turbine; and

Figure 6   is a sectional view of part of the
turbine portion of the turbocharger and of the atuator
assembly for the control system of Figure 5.

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Referring now to Figure 1, an internal combustion
engine 10 is fitted with a turbosupercharger
(turbocharger) 12. The turbocharger 12 comprises a
turbine portion 14 which receives exhaust gases from
5   the engine 10 and extracts a portion of the energy in
the exhaust stream to drive a compressor portion 16
which compresses ambient air and delivers it to the
engine so that the engine can produce more power and
generally operate more efficiently. In order to focus
10   on the present invention, certain details of the type
of engine and engine/turbocharger interconnection have
been omitted. However, persons skilled in the art
should realize that suitable manifolds will be
provided between the various portions of the
15   turbocharger and the engine cylinders. Furthermore
the engine may be either a spark ignition or
compression ignition (diesel) type.

In order to achieve greater engine operating
20   flexibility and efficiency. the turbine portion 14 has
a variable effective area, an example of which will be
described below. The exact form of the mechanism may
be selected from any one of a number of variable
geometry schemes set out in the previously mentioned

FLAXINGTON and SZCZUPAK paper and still achieve the
benefits of the present invention.

In the present invention, a control system 20
varies the effective area of the turbine portion 14 so
that it is a predetermined function of engine rpm,
exemplified by the graph in Figure 2. In Figure 2,
the effective area is displayed along the vertical
axis and the engine rpm is displayed along the
horizontal axis. The curve 22 includes a first
portion I which is at or approximates to the maximum
power condition of the engine 10. The magnitude of
the area in this portion is generally constant and is
established by the maximum permissible cylinder
working pressure. This portion of the curve is
generally constant because the need for reduced
swallowing capacity does not occur until the break
point 23 of the curve is reached.

The second portion II of the curve 22 occurs at a
lower engine rpm at or approximating to the condition
of maximum torque. It has been found that the area
maintained in portion II is substantially reduced from
the area in portion I and preferably is a reduction of
approximately sixty per cent. Any reduction

significantly beyond sixty per cent will result in
pumping losses across the obstructed area that offset
any gains to be realized by an increase in compressor
boost. The third portion III between I and II defines
5   an effective area that increases as function of engine
rpm. This function of engine rpm may be modified by
any one or combination of a number of engine operating
parameters such as maximum cylinder operating
pressures, cylinder temperatures, exhaust temperature,
10   or emissions e.g. smoke. If the variable effective
area device is chosen to be a turbine inlet nozzle as
mentioned below, it is preferable that the turbine
inlet nozzle be varied as a linear function of engine
rpm in portion III. However, other relationships may
15   be employed as illustrated by the dashed line in
Figure 2.

The above relationship has been found to result
in the best compromise between transient engine
20   response, i.e. rapid increase in manifold boost during
acceleration and the nozzle area which gives optimum
fuel efficiency at high engine rpm.

In order to achieve the control function set out above, the control system 20 comprises a variable area nozzle assembly 24 actuated by one or more actuating devices 26 organised by controller 28 via line 30.

5 The controller 28 generates appropriate control signals to energize the variable area system in such a way that the curve of Figure 2 is realized using a primary independent variable input from a line 32 connected to an rpm signal generating device 34

10 mechanically or electronically connected to engine 10 via connection 36 to generate a signal directly proportioned to engine rpm.

. The controller 28 may be analog or digital

15 depending on the particular system needs and the actuating device 26 may take a number of forms illustrated in succeeding paragraphs. The actuating device may be an electrically energized stepper motor which has the capability of generating an inherent

20 feedback signal to the controller 28 so that the nozzle area is corrected to maintain the predetermined schedule of Figure 2.

Additional control functions may be employed in
the system 20 to temporarily maintain the inlet nozzle
assembly 24 in a specified operating condition. For
example, a signal generating device or switch 38 is

5   reponsive to engine coolant temperature and
communicates with controller 28 via line 40 to maintain
the inlet nozzle assemby 24 in a minimum area
condition whenever the engine is below a certain
temperature representing cold operating conditions to

10   minimize and preferably eliminate white smoke
emissions if engine 10 is a diesel.

The discussion below will show alternative
systems and where possible, like numbers will be used

15   to indicate generally like components. Referring to
Figures 3 and 4, the turbine portion 14 comprises a
housing 42 which contains a rotatable centripetal
turbine wheel 44 mounted on a shaft 46 which is
journalled in bearing assembly 48 and connected to the

20   compressor 16 (not shown in Figure 4). Exhaust gases
are admitted to the wheel 44 past an annular nozzle
passage 50 having a plurality of vanes 52 which direct
gases flowing inward in the appropriate tangential
direction. The flow area of the nozzle passage 50 is

25   varied by an annular control ring 54 whish is slotted

to embrace vanes 52 and to variably obstruct nozzle
passage 50. The control ring 54 is translatable into
and out of nozzle passage 50 by an output shaft 56 of
the actuator assembly 26, by means of a flange 58.

5   The actuator assembly 26 comprises a first formed
housing 60 fixed to the turbine and through which
shaft 56 extends to flanges 62, 64 which sandwich a
diaphragm 66. Diaphragm 66 has its outer perimeter
sandwiched between housing 60 and a second housing 68,

10   suitably fixed to one another. Diaphragm 66 and
housing 60 define a variable volume chamber 70 which
is pressurized through line 72 to a controlled level.
A spring 74 in housing 68 acts on diaphragm 66 in
opposition to the force generated on it by the

15   pressure in chamber 70. The spring 74, as illustrated
in Figure 4, may have a force versus displacement
characteristic such that the pressure in chamber 70 is
directly proportional to the displacement of shaft 56,
and therefore the area of nozzle passage 50.

20

       The pressure in chamber 70 is controlled by a
solenoid valve 76 (Figure 3) connected to a
pressurized fluid (such as air) tank 78 by a line 80.
Solenoid valve 76 may be of the type that is a

25   pressure regulating valve in response to electrical

signals from controller 28 via line 82 or maybe an
on/off valve.

5   The valve 76 is adapted to admit controlled shots
of pressurized air from tank 78 to maintain the
appropriate pressure in chamber 70. In order to
permit controlled reduction of pressure in chamber 70,
it is continuously bled, for example, by providing a
clearance between shaft 56 and housing 60.

10

       Controller 28 sends to solenoid valve 76
electrical pulses of appropriate duration in response
to the predetermined schedule established according to
Figure 2 and the independent control inputs provided
15   by rpm signal generator 34. In order to provide a
feedback function for this system, a pressure sensor
83 is connected so as to sense the pressure in chamber
70 and supply an electrical signal via line 84 to
controller 28. As noted above, the pressure in chamber
20   70 bears a directly proportional relationship to the
area of nozzle passage 50 making the pressure signal a
convenient signal to feedback the actual nozzle area
to controller 28.

An example of a suitable controller 28 can be an analog controller operating on a comparison of dc voltages, one which is from an analog-to-digital converter receiving a signal from a magnetic pickup

5   transducer 36 and modified to produce the schedule of Figure 2. The other voltage is generated by the pressure sensor 83. The resultant error signal is converted into a series of variable width electrical pulses which are applied to solenoid valve 76.

10   Solenoid valve 76 opens and closes to control pressure in chamber 70 and thus the flow area of nozzle passage 50.

There are some circumstances under which it is

15   desired to include an additional control function for the system of Figures 3 and 4. When diesel engines are used for vehicular power, it may be required that an engine exhaust brake be provided at the output from the turbine 14 to selectively obstruct exhaust flow

20   from the engine 10, thus giving it a retarding capability which slows down a vehicle. For example guillotine type exhaust brake 86 is illustrated and it receives an actuating signal from line 88 and control valve 90 which selectively connects pressurized fluid

25   in tank 78 through line 92.

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When valve 90 blocks flow, the air being compressed by the engine heats up significantly and may elevate temperatures around the turbine to the point where it may be harmful to the diaphragm 66

5 which is usually made from elastomeric material. In order to alleviate this condition, a suitable operation sensor 94 located on the brake 86 sends a signal via line 96 to controller 28 which causes valve 76 to be selectively maintained in a position that

10 permits pressurized fluid at a sufficiently high level to be delivered to chamber 70 and bleed out past shaft 56 thereby cooling diaphragm 66.

The control system of Figures 3 and 4 utilize a

15 feedback signal which is an inferred nozzle area signal by means of pressure transducer 83. It may be desirable in some cases to use a signal that represents actual movement of shaft 56 and thus the flow area of nozzle passage 50. The control system of

20 Figures 5 and 6 does this by incorporating on housing 68 a displacement transducer 98 which has a rod 100 fixed to the end of shaft 56. Transducer 98 generates a signal and sends it to the controller 28 through line 84 to appropriately correct the control signal

25 from controller 28. The advantage of this type of

signal is that it can detect when the control ring 58
is prevented from moving thereby permitting the
incorporation in the controller of a warning signal
device.

CLAIMS

1. In an internal combustion engine having a
turbosupercharger (12) including a compressor (16) and
a turbine (14) and a means (24) for varying the
effective area of the turbine, comprising:

(a) means (26) for actuating said means (24) for
varying the effective area of the turbine (14) to
achieve an effective area as a predetermined function
of engine rpm, said function comprising a first
portion (I) at high rpms that maintains the effective
area substantially in its maximum area condition as
established by peak engine operating pressures and a
second portion (II) at lower rpms which maintains the
effective area substantially in the minimum area
condition and a third portion (III) intermediate the
first and second portions and having a characteristic
that the effective area increases as an increasing
function of engine rpm as established by selected
engine operating parameters;

(b) means (83) for generating a feedback signal
representing the actual effective area and feeding
said signal back to control means (28) and said

control means (28) being responsive to the feedback

signal to generate pulses applied to said actuating

means (26) to correct the means (24) for varying the

effective area of the turbine (14) to achieve said

5   effective area as a predetermined function of engine

rpm.

2.   Apparatus as claimed in Claim 1 wherein the

minimum effective area is approximately 40% of the

10   maximum.

3.   Apparatus as claimed in Claim 1 wherein the

first portion of the area versus rpm function is at

rpms at and adjacent those resulting in maximum power

15   for said engine and the second portion of the area

versus rpm function is at rpms lower than those

resulting in peak torque for said engine.

4.   Apparatus as claimed in Claim 1 wherein said

20   actuating means comprises:

(a)   an actuator (26);

(b)   said control means (28) energising said

actuator (26) as a function of a plurality of control

inputs, including the feed back signal from said means

25   (24) for varying the effective area of the turbine

(14);

(c) means (34) for generating a signal as a direct function of engine rpm and applying said signal to said control means, (28) whereby said control means (28) energises said actuator (26) in response to engine rpm as corrected by the feedback signal.

5. Apparatus as claimed in Claim 4 wherein said actuator (26) is responsive to electrical signals and said control means (28) generates electrical signals to energise said actuator (26).

6. Apparatus as claimed in Claim 5 wherein said actuator (26) comprises said means (83) for providing a feedback signal representing its actual displacement thereby providing the feedback signal to said controller means.

7. Apparatus as claimed in Claim 4 wherein said actuator (26) is responsive to fluid pressure and said control means (28) is connected to a source of fluid pressure (78) for generating fluid pressure signals to energise said actuator (26).

8. Apparatus as claimed in Claim 7 wherein said actuator (26) comprises:

(a) a displaceable shaft (56) for connection with said means (24) for varying the effective area of
5 the turbine (14);

(b) means (60,66) connected to said shaft (56) for defining a variable volume chamber (70) connected to said control means (28) receiving pressure signals from said control means (28) and
10 displacing said shaft (56);

(c) means (74) for yieldably urging said shaft (56) in a direction to reduce the variable volume chamber (70) whereby displacement of said shaft (56) is a direct function of fluid pressure.

15

9. Apparatus as claimed in claim 8 wherein said yieldable urging means comprises a spring (74) having a linear force/displacement characteristic;

said feedback means comprises a pressure
20 transducer (83) connected to said variable volume chamber means (70) for producing a pressure signal directly proportional to the displacement of said shaft (56).

10. Apparatus as claimed in Claim 7 wherein said control means comprises:

(a) a solenoid valve (76) for supplying fluid to said actuator (26) at a controlled pressure;

(b) an electrical controller (28) for supplying electrical signals to said solenoid valve, (76) and said rpm signal means (34) generating a signal usable by said electrical controller (28).

11. Apparatus as claimed in Claim 10 wherein said solenoid valve (76) is an on/off valve and the electrical controller (28) is adapted to generate pulse signals to said valve (76) to regulate the pressure.

12. Apparatus as claimed in Claim 7 wherein said actuator (26) is adapted to continuously bleed through said fluid whereby said fluid acts to cool said actuator (26).

13. Apparatus as claimed in Claim 7 further comprising an engine temperature sensor (38) providing a control input which prevents control of the area varied by said means for varying the effective area to

any area but the minimum when engine temperature is
below a given level.

20

28

FIG.1

30

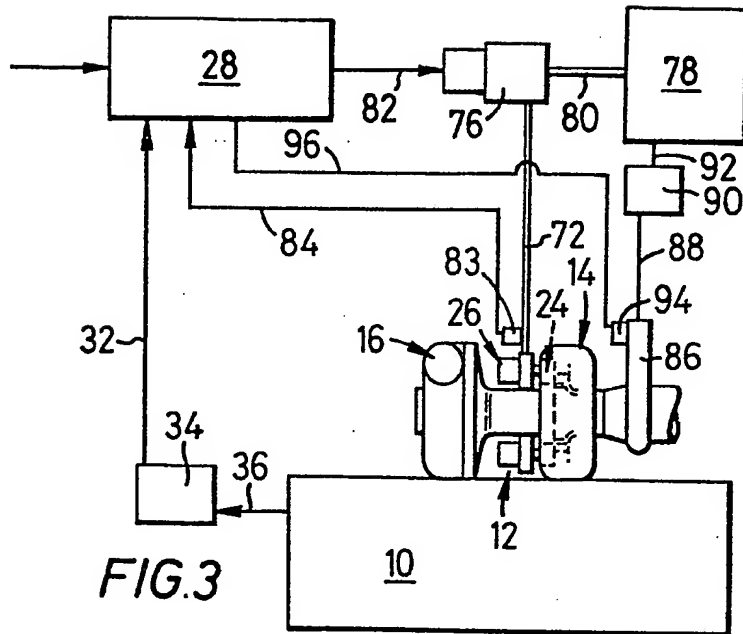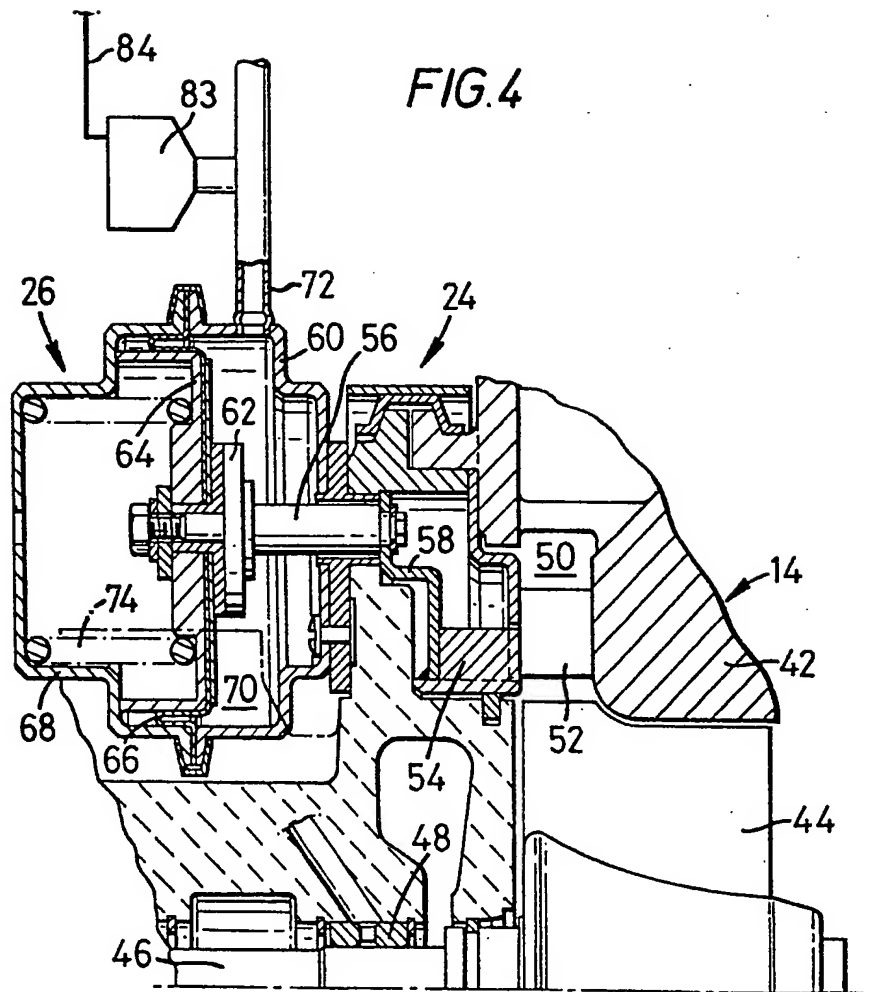40

16 26 24 14

32

34 36 38

12 10

FIG.2

II   III   I

23

TURBINE
AREA   22

ENGINE RPM
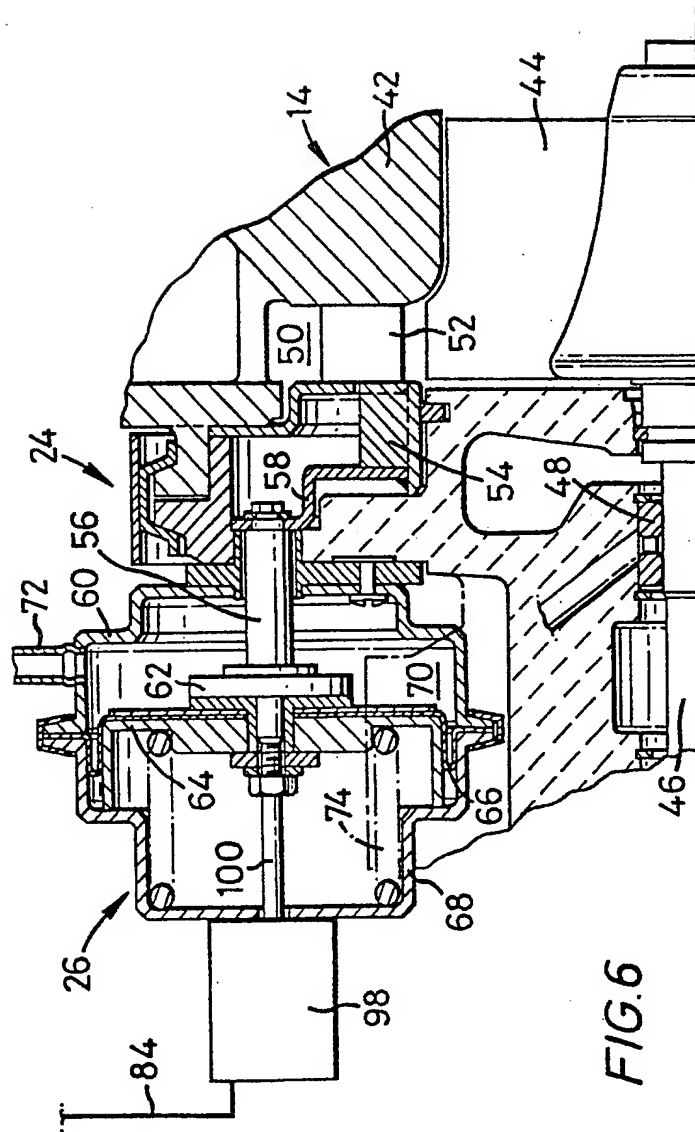
FIG.3

FIG.5

FIG.4

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FIG.6
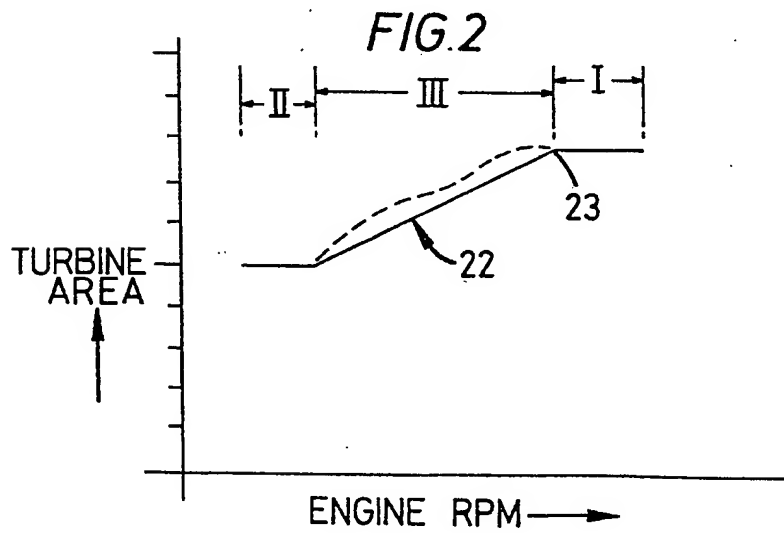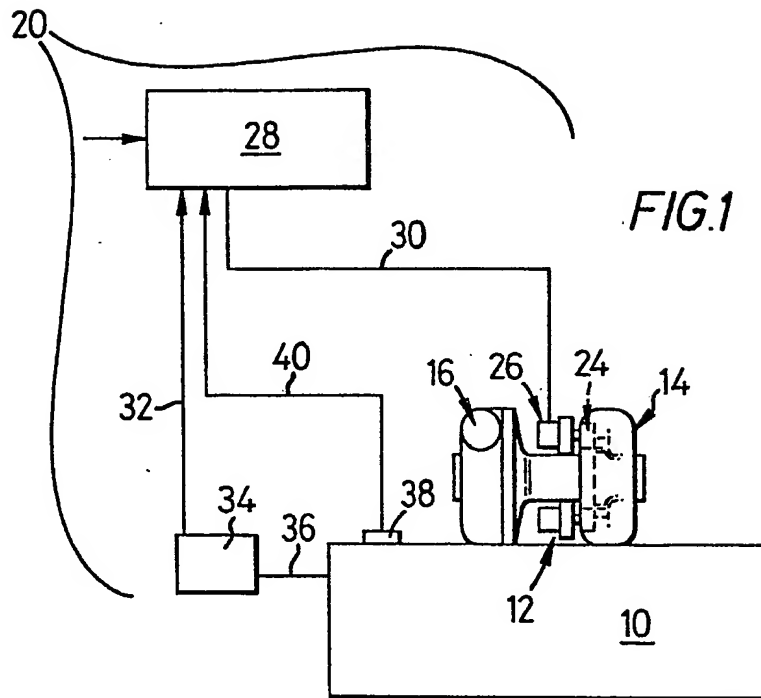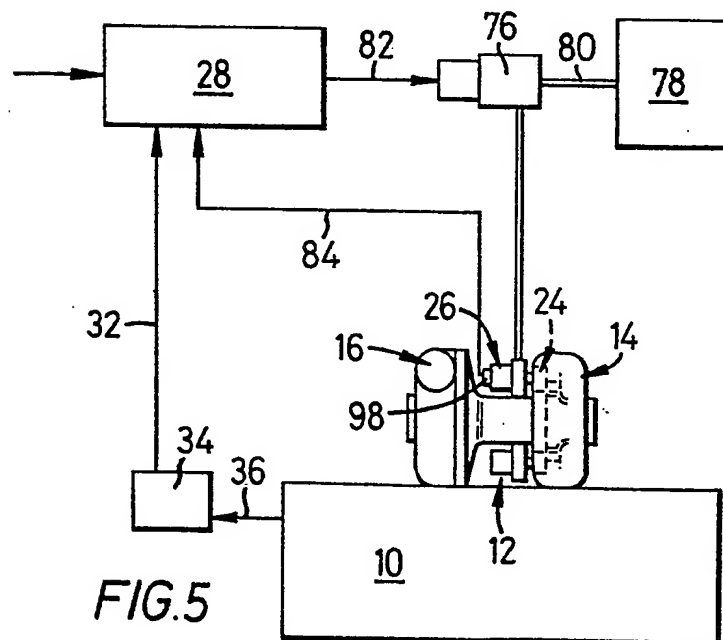
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EUROPEAN SEARCH REPORT

0136858
Application number

EP 84 30 6273

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	US-A-4 291 535 (GOLOFF) * Figure 5; column 11, line 4 - column 13, line 28 *	1	F 01 D 17/14
A		4,5	
Y	US-A-4 292 807 (RANNENBERG) * Column 4, lines 7-44 *	1	
A		3,4,7,8	
A	US-A-3 149 820 (A.M. MARO) * Figure 1; column 2, line 39 - column 3, line 24 *	1,4,5,7,8	
A	EP-A-0 080 810 (HOLSET) * Whole document *	1,4,7-9	TECHNICAL FIELDS SEARCHED (Int. Cl. ³) F 01 D F 04 D F 02 B
A	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 177(M-233)(1322), 5th August 1983; & JP - A - 58 79622 (NISSAN JIDOSHA K.K.) 13-05-1983	1,10,11	
A	FR-A- 862 954 (LUCHSINGER) * Whole document *	1,13	

-/-

The present search report has been drawn up for all claims

Place of search THE HAGUE	Date of completion of the search 18-01-1985	Examiner MC GINLEY C.J.

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EUROPEAN SEARCH REPORT

	DOCUMENTS CONSIDERED TO BE RELEVANT		Page 2
Category	Citation of document with indication. where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	GB-A- 213 243 (BÜCHI) * Whole document * ---	1	
A	GB-A- 691 144 (BÜCHI) * Whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

The present search report has been drawn up for all claims

Place of search THE HAGUE	Date of completion of the search 18-01-1985	Examiner MC GINLEY C.J.

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